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(54) **DATA TRANSMISSION APPARATUS AND COMMUNICATION SYSTEM USING A CONSTELLATION REARRANGEMENT**

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(57) **ABSTRACT**

A hybrid ARQ retransmission method in a communication system, wherein data packets being encoded with a forward error correction (FEC) technique prior to transmission, are retransmitted based on an automatic repeat request and subsequently soft-combined with previously received erroneous data packets either on a symbol-by-symbol or a bit-by-bit basis The symbols of said erroneous data packets are modulated by employing a predetermined first signal constellation. The symbols of the retransmitted data packets are modulated by employing at least a predetermined second signal constellation. Each symbol bit has a mean bit reliability defined by the individual bit reliabilities over all symbols of the predetermined signal constellation. According to the invention, the predetermined first and the at least second signal constellation are selected such that the combined mean bit reliabilities for the respective bits of all transmissions are averaged out.
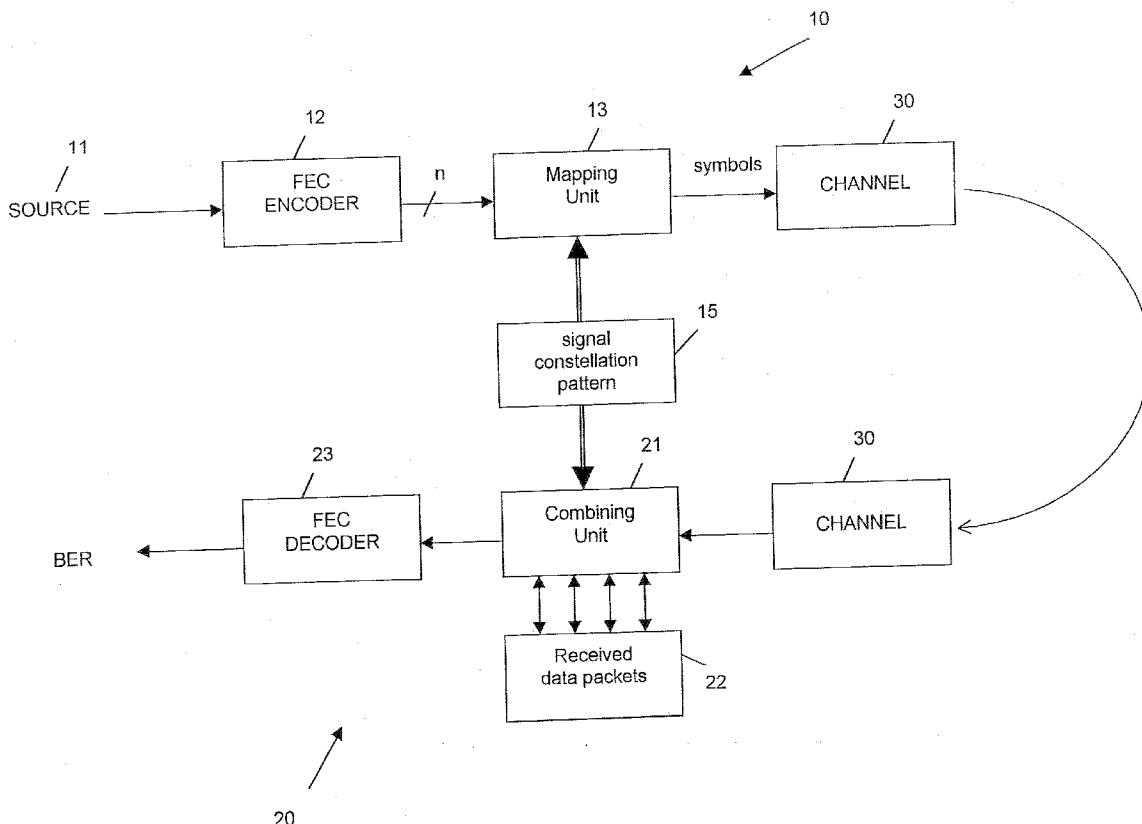
i_1

i_2 i_2

1011	1001	0001	0011
●	●	●	●

q_2

1010	1000	0000	0010
●	●	●	●

q_1 q_2

●	●	●	●
1110	1100	0100	0110

●	●	●	●
1111	1101	0101	0111

Figure 1

Constellation 2

0000 ●	0100 ●	0101 ●	0001 ●
1000 ●	1100 ●	1101 ●	1001 ●
1010 ●	1110 ●	1111 ●	1011 ●
0010 ●	0110 ●	0111 ●	0011 ●

i_1 i_2 q_1 q_2 Re Im

Constellation 1

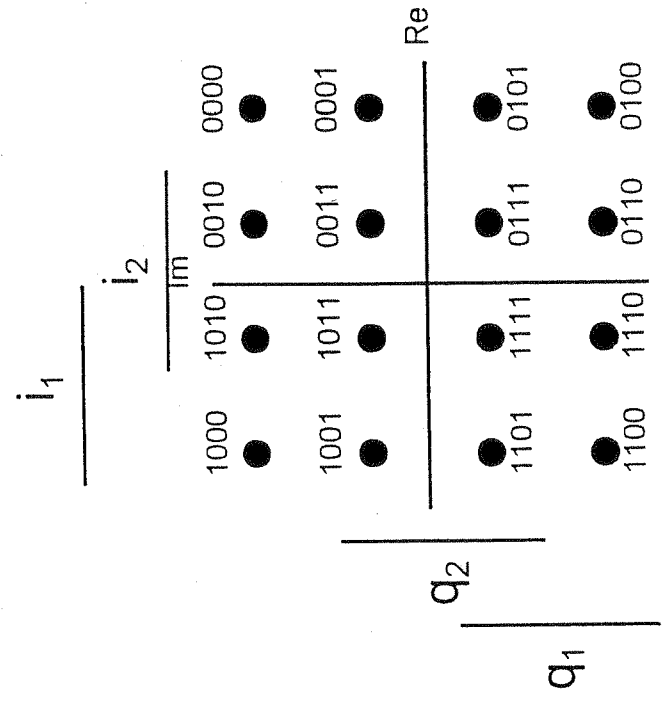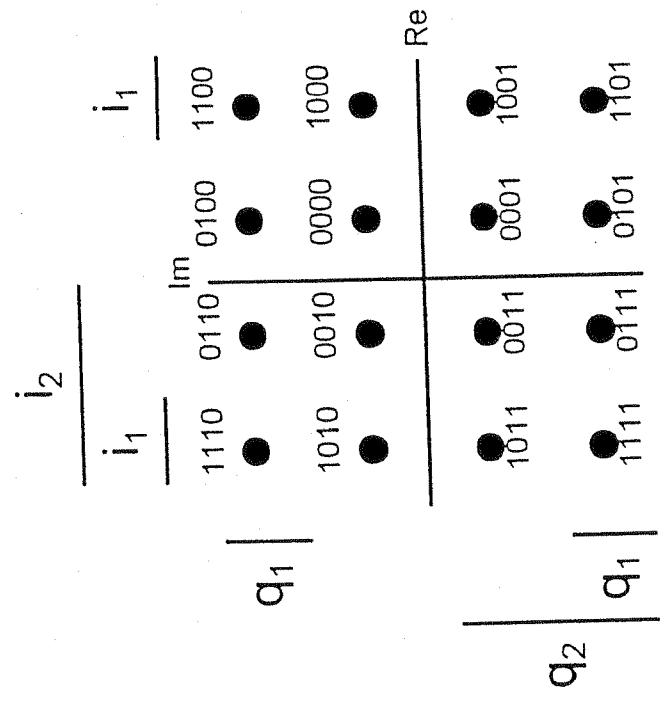|			
0011 ●	0010 ●	0110 ●	0111 ●
0001 ●	0000 ●	0100 ●	0101 ●
1001 ●	1000 ●	1100 ●	1101 ●
1011 ●	1010 ●	1110 ●	1111 ●

i_1 i_2 q_1 q_2 Re Im

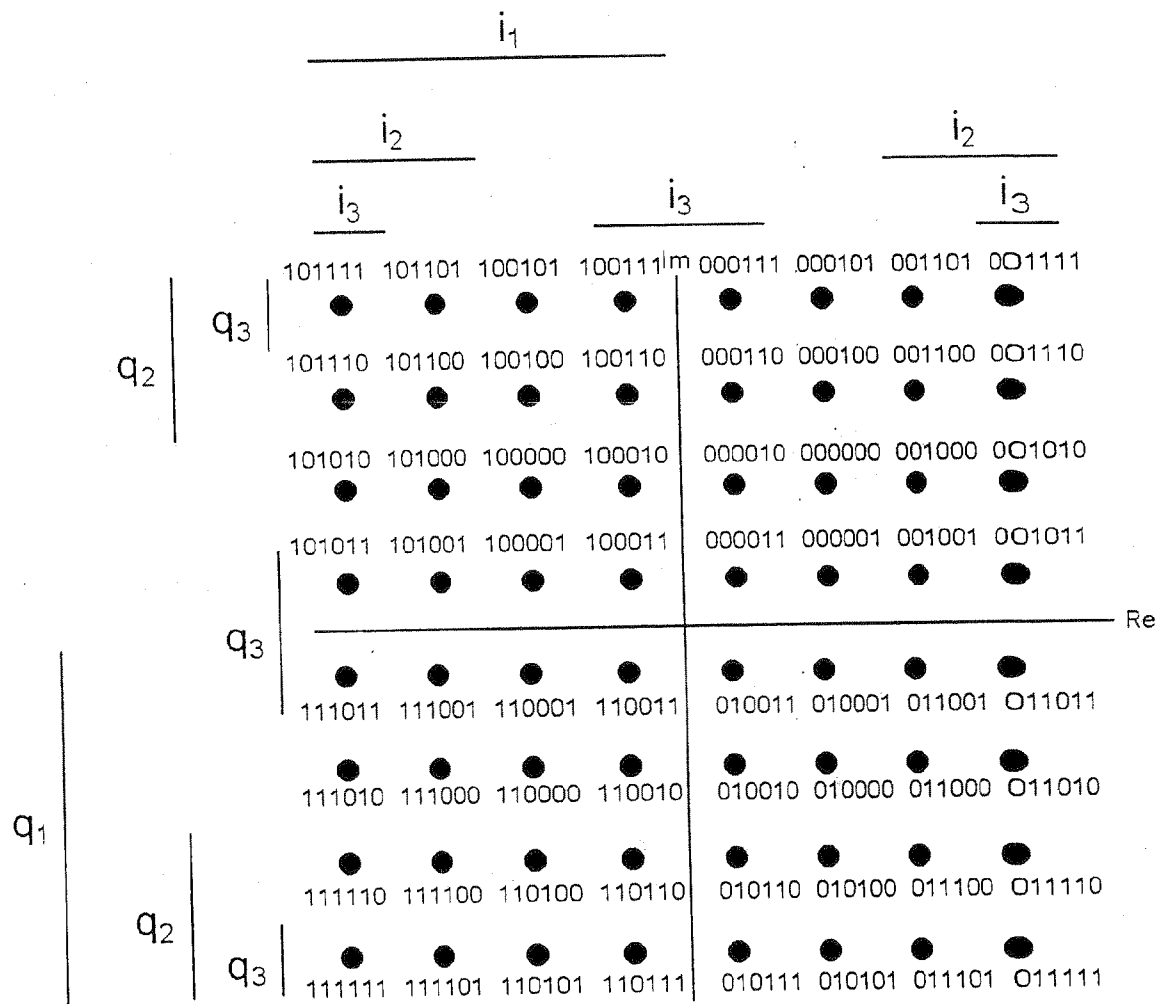## Figure 2 a

Constellation 4
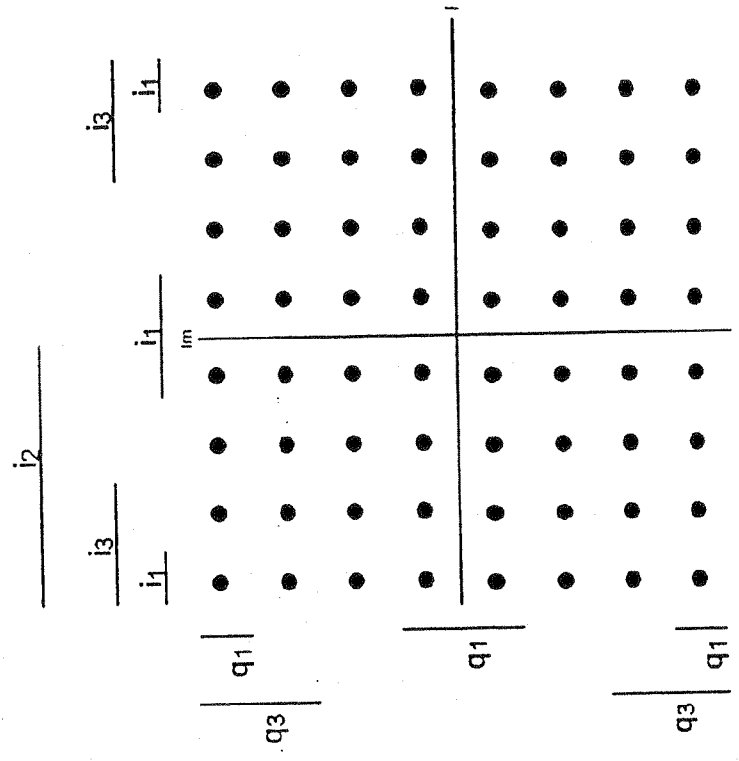
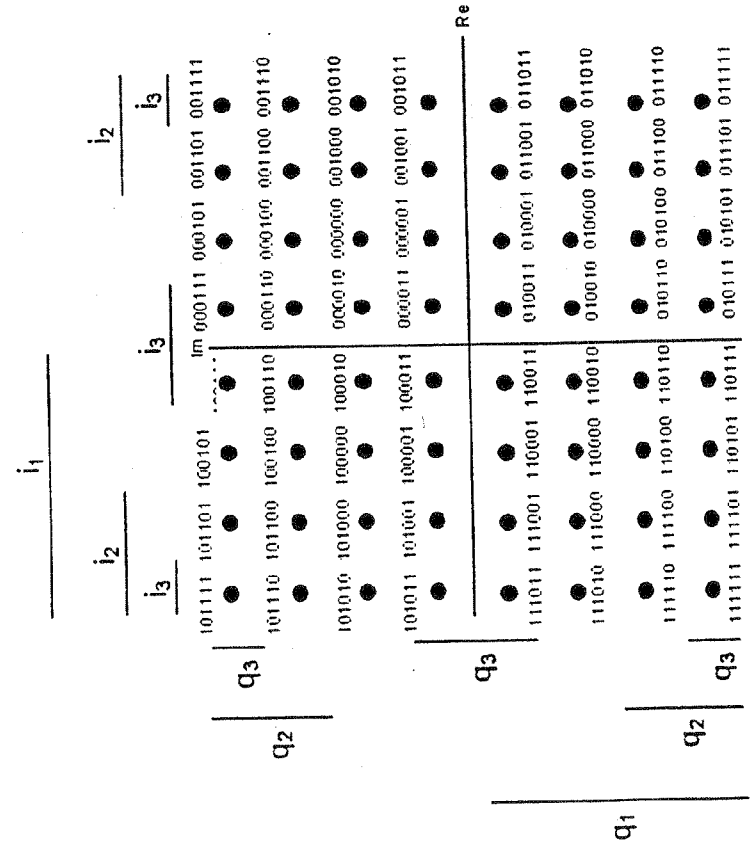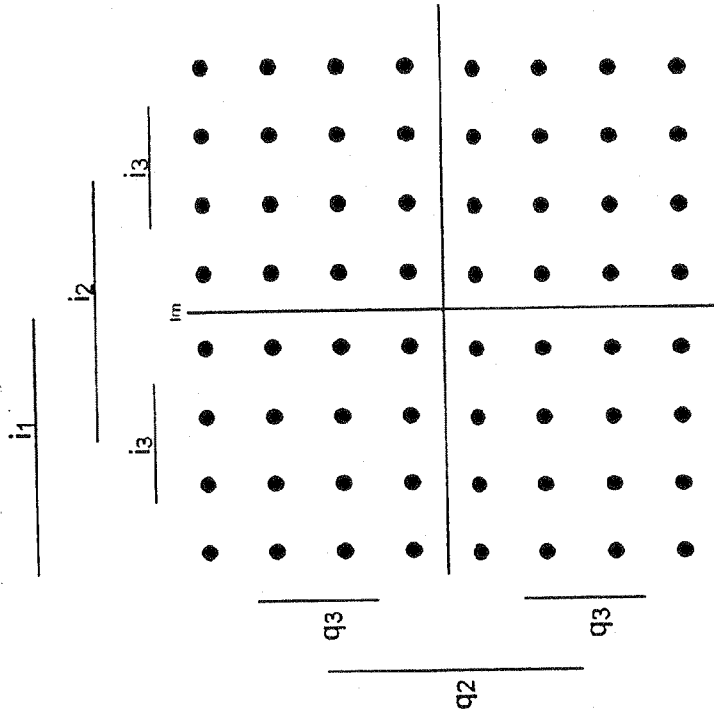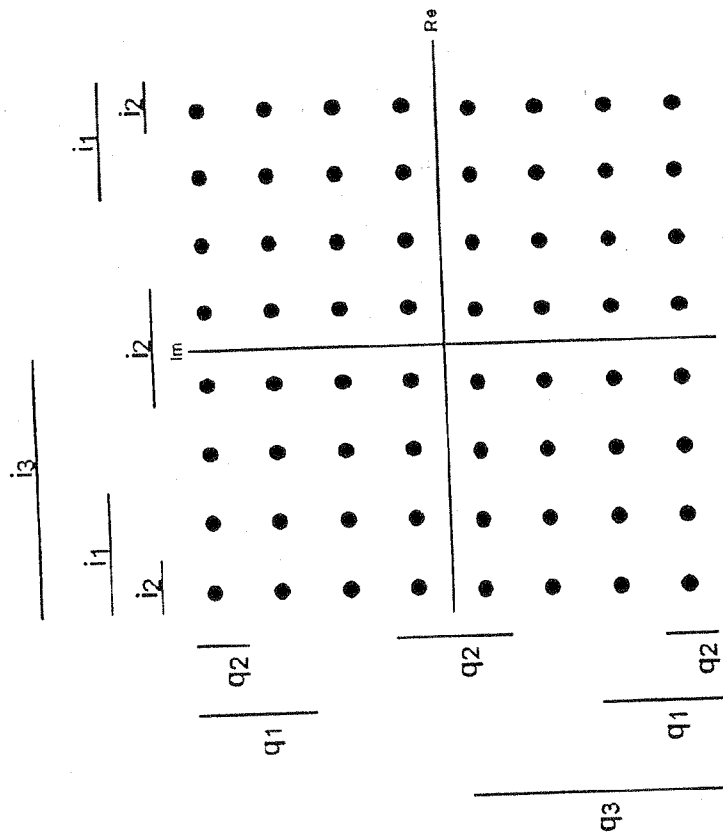Constellation 3

Figure 2 b

Figure 3

Constellation 2

Constellation 1
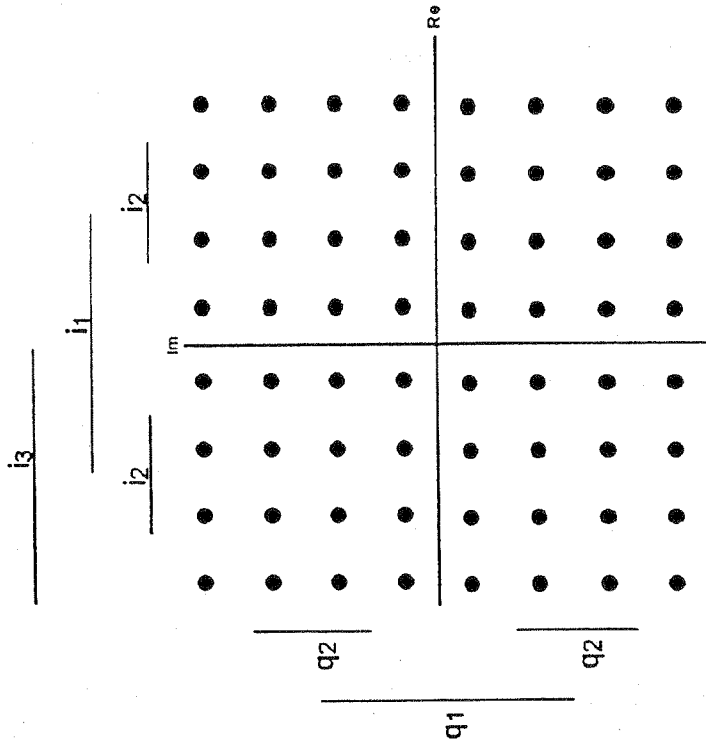
Figure 4 a

Constellation 4
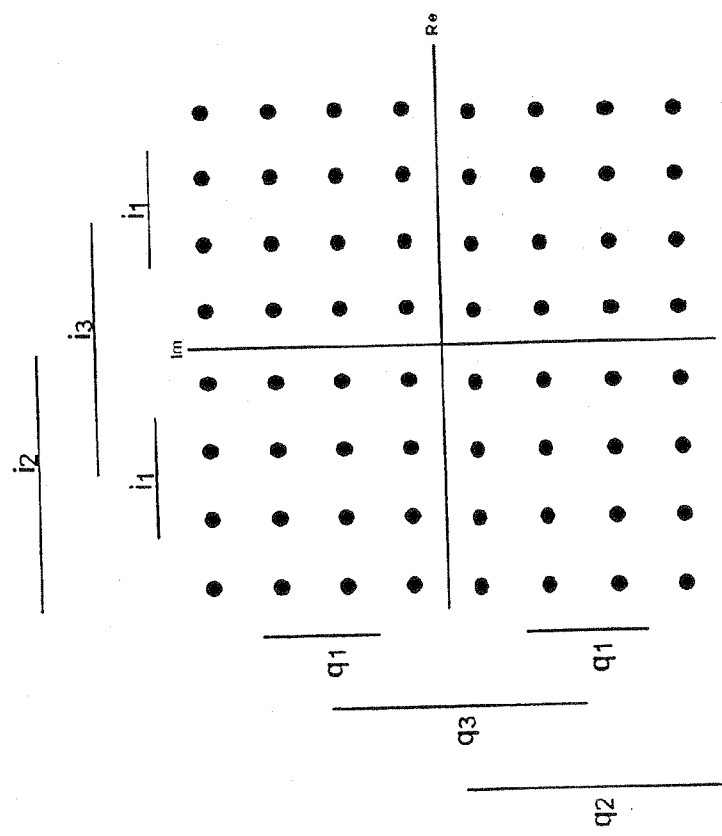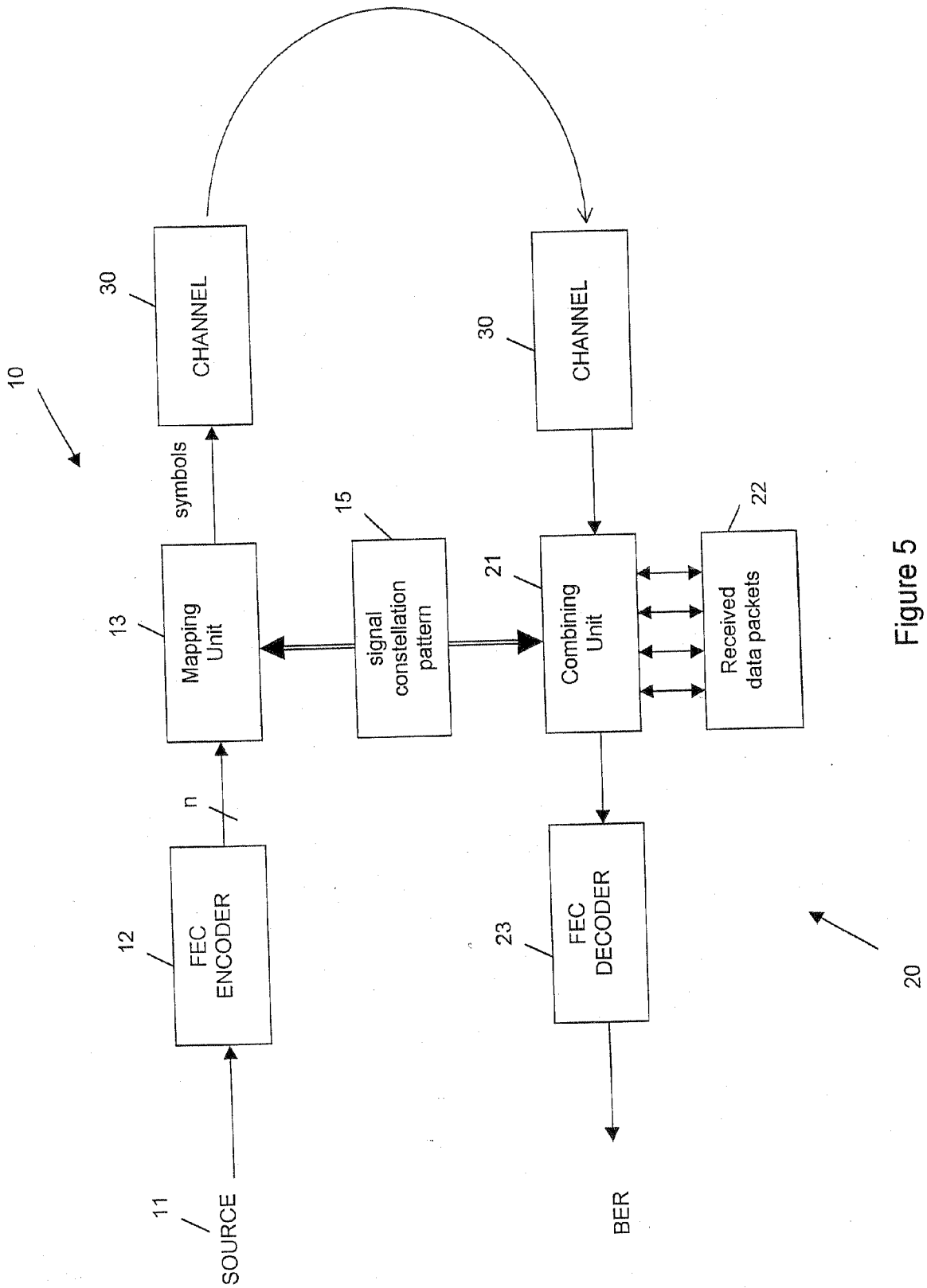

Constellation 3

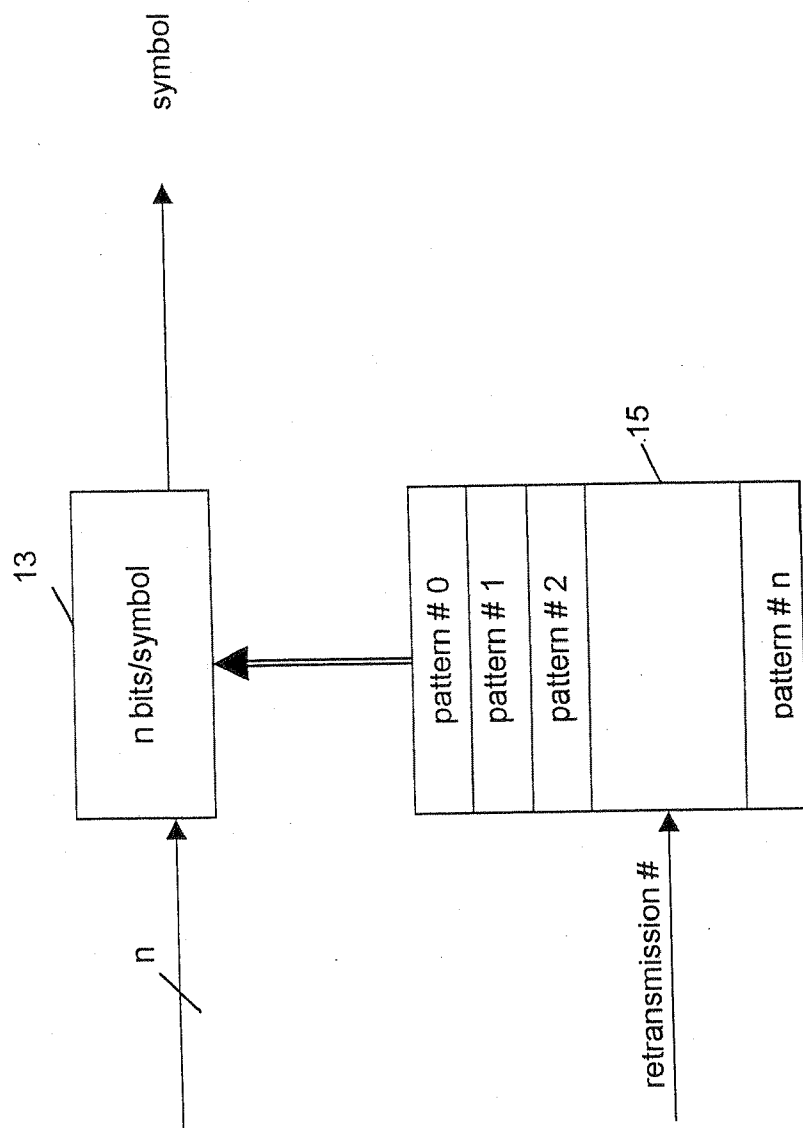Figure 4 b

Figure 4 c

Figure 5

Figure 6

DATA TRANSMISSION APPARATUS AND COMMUNICATION SYSTEM USING A CONSTELLATION REARRANGEMENT

[0001] This is a continuation of application Ser. No. 11/003,437 filed Dec. 6, 2004, which is a continuation of application Ser. No. 101239,794 filed Sep. 25, 2002, now U.S. Pat. No. 6,892,341 B2, issued May 10, 2005.

FIELD OF THE INVENTION

[0002] The present invention relates to a hybrid ARQ retransmission method in a communication system.

BACKGROUND OF THE INVENTION

[0003] A common technique in communication systems with unreliable and time-varying channel conditions is to correct errors based on automatic repeat request (ARQ) schemes together with a forward error correction (FEC) technique called hybrid ARQ (HARQ). If an error is detected by a commonly used cyclic redundancy check (CRC), the receiver of the communication system requests the transmitter to resend the erroneously received data packets.

[0004] S. Kaliel, Analysis of a type II hybrid ARQ scheme with code combining, IEEE Transactions on Communications, Vol. 38, No. 8, August 1990 and S. Kallel, R. Link, S. Bakhtiyari, Throughput performance of Memory ARQ schemes, IEEE Transactions on Vehicular Technology, Vol. 48, No. 3, May 1999 define three different types of ARQ schemes:

[0005] Type I: The erroneous received packets are discarded and a new copy of the same packet is retransmitted and decoded separately. There is no combining of earlier and later received versions of that packet.

[0006] Type II: The erroneous received packets are not discarded, but are combined with some incremental redundancy bits provided by the transmitter for subsequent decoding. Retransmitted packets sometimes have higher coding rates and are combined at the receiver with the stored values. That means that only little redundancy is added in each retransmission.

[0007] Type III: Is the same as Type II with the constraint each retransmitted packet is now self-decodable. This implies that the transmitted packet is decodable without the combination with previous packets. This is useful if some packets are damaged in such a way that almost no information is reusable.

[0008] Types II and III schemes are obviously more intelligent and show a performance gain with respect to Type I, because they provide the ability to reuse information from of previously received erroneous packets. There exist basically three schemes of reusing the redundancy of previously transmitted packets:

[0009] Soft-Combining

[0010] Code-Combining

[0011] Combination of Soft- and Code-Combining

Soft-Combining

[0012] Employing soft-combining the retransmission packets carry identical symbols compared with the previ-ously received symbols. In this case the multiple, received packets are combined either by a symbol-by-symbol or by a bit-by-bit basis as for example disclosed in D. Chase, Code combining: A maximum-likelihood decoding approach for combining an arbitrary number of noisy packets, IEEE Trans. Commun., Vol. COM-33, pp. 385-393, May 1985 or B. A. Harvey and S. Wicker, Packet Combining Systems based on the Viterbi Decoder, IEEE Transactions on. Communications, Vol. 42, No. 2/3/4, April 1994. By combining this soft-decision values from all received packets the reliabilities of the transmitted bits will increase linearly with the number and power of received packets. From a decoder point of view the same FEC scheme (with constant code rate) will be employed over all transmissions. Hence, the decoder does not need to know how many retransmissions have been performed, since it sees only the combined soft-decision values. In this scheme all transmitted packets will have to carry the same number of symbols.

Code-Combining

[0013] Code-combining concatenates the received packets in order to generate a new code word (decreasing code rate with increasing number of transmission). Hence, the decoder has to be aware of the FEC scheme to apply at each retransmission instant. Code-combining offers a higher flexibility with respect to soft-combining, since the length of the retransmitted packets can be altered to adapt to channel conditions. However, this requires more signaling data to be transmitted with respect to soft-combining.

Combination of Soft- and Code-Combining

[0014] In case the retransmitted packets carry some symbols identical to previously transmitted symbols and some code-symbols different from these, the identical code-symbols are combined using soft-combing as described in the section titled "Soft Combining" while the remaining code-symbols will be combined using code-combining. Here, the signaling requirements will be similar to code-combining.

[0015] As it has been shown in M. P. Schmitt, Hybrid ARQ Scheme employing TCM and Packet Combining, Electronics Letters Vol. 34, No. 18, September 1998 that HARQ performance for Trellis Coded Modulation (TCM) can be enhanced by rearranging the symbol constellation for the retransmissions. There, the performance gain results from the maximizing the Euclidean distances between the mapped symbols over the retransmissions, because the rearrangement has been performed on a symbol basis.

[0016] Considering high-order modulation schemes (with modulation symbols carrying more than two bits) the combining methods employing soft-combining have a major drawback: The bit reliabilities within soft-combined symbols will be in a constant ratio over all retransmissions, i.e. bits which have been less reliable from previous received transmissions will still be less reliable after having received further transmissions and, analogous, bits which have been more reliable from previous received transmissions will still be more reliable after having received further transmissions.

[0017] The varying bit reliabilities evolve from the constraint of two-dimensional signal constellation mapping, where modulation schemes carrying more than 2 bits per symbol cannot have the same mean reliabilities for all bits under the assumption that all symbols are transmitted

equally likely. The term mean reliabilities is consequently meant as the reliability of a particular bit over all symbols of a signal constellation.

[0018] Employing a signal constellation for a 16 QAM modulation scheme according to FIG. 1 showing a Gray encoded signal constellation with a given bit-mapping order $i_1q_1i_2q_2$, the bits mapped onto the symbols differ from each other in mean reliability in the first transmission of the packet. In more detail, bits i_1 and q_1 have a high mean reliability, as these bits are mapped to half spaces of the signal constellation diagram with the consequences that their reliability is independent from the fact of whether the bit transmits a one or a zero.

[0019] In contrast thereto, bits i_2 and q_2 have a low mean reliability, as their reliability depends on the fact of whether they transmit a one or a zero. For example, for bit i_2, ones are mapped to outer columns, whereas zeros are mapped to inner columns. Similarly, for bit q_2, ones are mapped to outer rows, whereas zeros are mapped to inner rows.

[0020] For the second and each further retransmissions the bit reliabilities will stay in a constant ratio to each other, which is defined by the signal constellation employed in the first transmission, i.e. bits i_1 and q_1 will always have a higher mean reliability than bits i_2 and q_2 after any number of retransmissions.

SUMMARY OF THE INVENTION

[0021] The object underlying the present invention is to provide a hybrid ARQ retransmission method with an improved error correction performance. This object is solved by a method as set forth in claim 1.

[0022] The method subject to the invention is based on the recognition that in order to enhance the decoder performance, it would be quite beneficial to have equal or near to equal mean bit reliabilities after each received transmission of a packet. Hence, the idea underlying the invention is to tailor the bit reliabilities over the retransmissions in a way that the mean bit reliabilities get averaged out. This is achieved by choosing a predetermined first and at least second signal constellation for the transmissions, such that the combined mean bit reliabilities for the respective bits of all transmissions are nearly equal.

[0023] Hence, the signal constellation rearrangement results in a changed bit mapping, wherein the Euclidean distances between the modulation symbols can be altered from retransmission to retransmission due to the movement of the constellation points. As a result, the mean bit reliabilities can be manipulated in a desired manner and averaged out to increase the performance the FEC decoder at the receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] For a more in depth understanding of the present invention, preferred embodiments will be described in the following with reference to the accompanying drawings.

[0025] FIG. 1 is an exemplary signal constellation for illustrating a 16 QAM modulation scheme with Gray encoded bit symbols,

[0026] FIG. 2 shows four examples for signal constellations for a 16 QAM modulation scheme with Gray encoded bit symbols,

[0027] FIG. 3 shows an exemplary signal constellation for 64-QAM Gray encoded bit symbols,

[0028] FIG. 4 shows six exemplary signal constellations for 64-QAM Gray encoded bit symbols

[0029] FIG. 5 is an exemplary embodiment of a communication system in which the method underlying the invention is employed, and

[0030] FIG. 6 explains details of the mapping unit shown in FIG. 5.

DETAILED DESCRIPTION OF EMBODIMENTS

[0031] For a better understanding of the embodiments, in the following the concept of a Log-Likelihood-Ratio (LLR) will be described as a metric for the bit reliabilities. First the straight forward calculation of the bit LLRs within the mapped symbols for a single transmission will be shown. Then the LLR calculation will be extended to the multiple transmission case.

Single Transmission

[0032] The mean LLR of the i-th bit $b_n{}^i$ under the constraint that symbol s_n has been transmitted for a transmission over a channel with additive white gaussian noise. (AWGN) and equally likely symbols yields

$$LLR_{b_n^i|r_n}(r_n) = \log\left[\sum_{(m|b_m^i = b_n^i)} e^{-\frac{E_S}{N_0} \cdot d_{n,m}^2}\right] - \log\left[\sum_{(m|b_m^i \neq b_n^i)} e^{-\frac{E_S}{N_0} \cdot d_{n,m}^2}\right], \quad (1)$$

where $r_n = s_n$ denotes the mean received symbol under the constraint the symbol s_n has been transmitted (AWGN case), $d_{n,m}{}^2$ denotes the square of the Euclidean distance between the received symbol r_n and the symbol s_m, and E_S/N_0 denotes the observed signal-to-noise ratio.

[0033] It can be seen from Equation (1) that the LLR depends on the signal-to-noise ratio E_S/N_0 and the Euclidean distances $d_{n,m}$ between the signal constellation points.

Multiple Transmissions

[0034] Considering multiple transmissions the mean LLR after the k-th transmission of the i-th bit $b_n{}^i$ under the constraint that symbols $s_n{}^{(j)}$ have been transmitted over independent AWGN channels and equally likely symbols yields

$$LLR_{b_n^i|\cap_{j=1}^k r_n^j}(r_n^{(1)}, r_n^{(2)}, \dots, r_n^{(k)}) = \quad (2)$$

$$\log\left[\sum_{(m|b_m^i = b_n^i)} e^{-\sum_{j=1}^k \left(\frac{E_S}{N_0}\right)^{(j)} \cdot \left(d_{n,m}^{(j)}\right)^2}\right] -$$

$$\log\left[\sum_{(m|b_m^i \neq b_n^i)} e^{-\sum_{j=1}^k \left(\frac{E_S}{N_0}\right)^{(j)} \cdot \left(d_{n,m}^{(j)}\right)^2}\right],$$

where j denotes the j-th transmission ((j−1)-th retransmission). Analogous to the single transmission case the mean

LLRs depend on the signal-to-noise ratios and the Euclidean distances at each transmission time.

[0035] If no constellation rearrangement is performed the Euclidean distances $d_{n,m}^{(j)}=d_{n,m}^{(1)}$ are constant for all transmissions and, hence, the bit reliabilities (LLRs) after k transmissions will be defined by the observed signal-to-noise ratio at each transmission time and the signal constellation points from the first transmission. For higher level modulation schemes (more than 2 bits per symbol) this results in varying mean LLRs for the bits, which in turn leads to different mean bit reliabilities. The differences in mean reliabilities remain over all retransmissions and lead to a degradation in decoder performance.

16-QAM Strategy

[0036] In the following, the case of a 16-QAM system will be exemplarily considered resulting in 2 high reliable and 2 low reliable bits, where for the low reliable bits the reliability depends on transmitting a one or a zero (see FIG. 1). Hence, overall there exist 3 levels of reliabilities.

[0037] Level 1 (High Reliability, 2 bits): Bit mapping for ones (zeros) separated into the positive (negative) real half space for the i-bits and the imaginary half space the q-bits. Here, there is no difference whether the ones are mapped to the positive or to the negative half space.

[0038] Level 2 (Low Reliability, 2 bits): Ones (zeros) are mapped to inner (outer) columns for the i-bits or to inner (outer) rows for the q-bits. Since there is a difference for the LLR depending on the mapping to the inner (outer) columns and rows, Level 2 is further classified:

[0039] Level 2a: Mapping of i_n to inner columns and q_n to inner rows respectively.

[0040] Level 2b: Inverted mapping of Level 2a: Mapping of i_n to outer columns and q_n to outer rows respectively.

[0041] To ensure an optimal averaging process over the transmissions for all bits the levels of reliabilities have to be altered by changing the signal constellations according to the algorithms given in the following section.

[0042] It has to be considered that the bit-mapping order is open prior initial transmission, but has to remain through retransmissions, e.g. bit-mapping for initial transmission: $i_1 q_1 i_2 q_2 \Rightarrow$ bit-mapping all retransmissions: $i_1 q_1 i_2 q_2$.

[0043] For the actual system implementation there are a number of possible signal constellations to achieve the averaging process over the retransmissions. Some examples for possible constellations are shown in FIG. 2. The resulting bit reliabilities according to FIG. 2 are given in Table 1.

TABLE 1

Bit reliabilities for 16-QAM according to signal constellations shown in FIG. 2

Constel-lation	bit i_1	bit q_1	bit i_2	bit q_2
1	High Reliability (Level 1)	High Reliability (Level 1)	Low Reliability (Level 2b)	Low Reliability (Level 2b)
2	Low Reliability (Level 2a)	Low Reliability (Level 2a)	High Reliability (Level 1)	High Reliability (Level 1)

TABLE 1-continued

Bit reliabilities for 16-QAM according to signal constellations shown in FIG. 2

Constel-lation	bit i_1	bit q_1	bit i_2	bit q_2
3	Low Reliability (Level 2b)	Low Reliability (Level 2b)	High Reliability (Level 1)	High Reliability (Level 1)
4	High Reliability (Level 1)	High Reliability (Level 1)	Low Reliability (Level 2a)	Low Reliability (Level 2a)

[0044] Moreover, Table 2 provides some examples how to combine the constellations for the transmissions 1 to 4 (using 4 different mappings).

TABLE 2

Examples for Constellation Rearrangement strategies for 16-QAM (using 4 mappings) with signal constellations according to FIG. 2 and bit reliabilities according to Table 1.

Trans-mission No.	Scheme 1 (with Constel-lations)	Scheme 2 (with Constel-lations)	Scheme 3 (with Constel-lations)	Scheme 4 (with Constel-lations)
1	1	1	1	1
2	2	2	3	3
3	3	4	2	4
4	4	3	4	2

[0045] Two algorithms are given which describe schemes using 2 or 4 mappings overall. The approach using 2 mappings results in less system complexity, however has some performance degradation with respect to the approach using 4 mappings. The mapping for i- and q-bits can be done independently and, hence, in the following the mapping for the i-bits only is described. The algorithms for the q-bits work analog.

16-QAM Algorithms

A. Using 2 Mappings

[0046] 1. Step (1. Transmission)

[0047] Choose Level 1 for $i_1 \Rightarrow$ Level 2 for i_2—free choice if 2a or 2b

$\Rightarrow$1. Mapping Defined

[0048] 2. Step (2. Transmission)

[0049] Choose Level 1 for $i_2 \Rightarrow$ Level 2 for i_1—free choice if 2a or 2b

$\Rightarrow$2. Mapping Defined

[0050] 3. Step

[0051] Options:

[0052] (a) Go to 1. Step and proceed with alternating between 1. and 2. Mapping

[0053] (b) Use 2. Mapping and proceed with using 2 times 1. Mapping, 2 times 2. Mapping and so on . . .

B. Using 4 Mappings

[0054] 1. Step (1. Transmission)

[0055] Choose Level 1 for i_1 ⇒Level 2 for i_2—free choice if $2a$ or $2b$

⇒1. Mapping Defined

[0056] 2. Step (2. Transmission)

[0057] Choose Level 1 for i_2 ⇒Level 2 for i_1—free choice if $2a$ or $2b$

⇒2. Mapping Defined

[0058] 3. Step (3. Transmission)

[0059] Options:

[0060] (a) Choose Level 1 for i_1 ⇒Level 2 for i_2 with following options

[0061] (a1) if in 1. Transmission $2a$ was used then use $2b$

[0062] (a2) if in 1. Transmission $2b$ was used then use $2a$

[0063] (b) Choose Level 1 for i_2 ⇒Level 2 for ii with following options

[0064] (b1) if in 2. Transmission $2a$ was used then use $2b$

[0065] (b2) if in 2. Transmission $2b$ was used then use $2a$

⇒3. Mapping Defined

[0066] 4, Step (4. Transmission)

[0067] if option (a) in 3. Step

[0068] Choose Level 1 for i_2 ⇒Level 2 for i_1 with following options

[0069] (a1) if in 2. Transmission $2a$ was used then use $2b$

[0070] (a2) if in 2. Transmission $2b$ was used then use $2a$ if option (b) in 3. Step

[0071] Choose Level 1 for i_1 ⇒Level 2 for i_2 with following options

[0072] (a1) if in 1. Transmission $2a$ was used then use $2b$

[0073] (a2) if in 1. Transmission $2b$ was used then use $2a$

⇒4. Mapping Defined

[0074] 5. Step (5., 9., 13., . . . Transmission)

[0075] Choose one out of 4 defined mappings

[0076] 6. Step (6., 10., 14., . . . Transmission)

[0077] Choose one out of 4 defined mappings except

[0078] (a) the mapping used in 5. Step (previous transmission)

[0079] (b) the mapping giving Level 1 reliability to the same bit as in previous transmission

[0080] 7. Step.(7., 11., 15., . . . Transmission)

[0081] Choose one out of 2 remaining mappings not used in last 2 transmissions

[0082] 8. Step (8., 12., 16., . . . Transmission)

[0083] Choose mapping not used in last 3 transmissions

[0084] 9. Step

[0085] Go to 5. Step

64-QAM Strategy

[0086] In case of a 64-QAM system there will be 2 high reliable, 2 medium reliable and 2 low reliable bits, where for the low and medium reliable bits the reliability depends on transmitting a one or a zero (see FIG. 3). Hence, overall there exist 5 levels of reliabilities.

[0087] Level 1 (High Reliability, 2 bits): Bit mapping for ones (zeros) separated into the positive (negative) real half space for the i-bits and the imaginary half space for the q-bits. Here, there is no difference whether the ones are mapped to the positive or to the negative half space.

[0088] Level 2 (Medium Reliability, 2 bits): Ones (zeros) are mapped to 4 inner and 2×2 outer columns for the i-bits or to 4 inner and 2×2 outer rows for the q-bits. Since there is a difference for the LLR depending on the mapping to the inner or outer column/row Level 2 is further classified:

[0089] Level 2a: Mapping of i_n to 4 inner columns and q_n to 4 inner rows respectively.

[0090] Level 2b: Inverted mapping of $2a$: i_n to outer columns and q_n to outer rows respectively

[0091] Level 3 (Low Reliability, 2 bits): Ones (zeros) are mapped to columns 1-4-5-8/2-3-6-7 for the i-bits or to rows 1-4-5-8/2-3-6-7 for the q-bits. Since there is a difference for the LLR depending on the mapping to columns/rows 1-4-5-8 or 2-3-6-7 Level 3 is further classified:

[0092] Level 3a: Mapping of i_n to columns 2-3-6-7 and q_n to rows 2-3-6-7 respectively

[0093] Level 3b: Inverted mapping of $2a$: i_n to columns 1-4-5-8 and q_n to rows 1-4-5-8 respectively

[0094] To ensure an optimal averaging process over the transmissions for all bits the levels of reliabilities have to be altered by changing the signal constellations according to the algorithms given in the following section.

[0095] It has to be considered that the bit-mapping order is open prior initial transmission, but has to remain through retransmissions, e.g. bit-mapping for initial transmission:

[0096] $i_1 q_1 i_2 q_2 i_3 q_3$ ⇒bit-mapping all retransmissions: $i_1 q_1 i_2 q_2 i_3 q_3$.

[0097] Analog to 16-QAM for the actual system implementation there are a number of possible signal constellations to achieve the averaging process over the retransmissions. Some examples for possible constellations are shown in FIG. 4. The resulting bit reliabilities according to FIG. 4 are given in Table 3.

TABLE 3

| Bit reliabilities for 64-QAM according to signal constellations shown in FIG. 4. | | | | | |
Constellation bit i_1	bit q_1	bit i_2	bit q_2	bit i_3	bit q_3
1	High Reliability (Level 1)	High Reliability (Level 1)	Middle Reliability (Level 2b)	Middle Reliability (Level 2b)	Low Reliability (Level 3b)	Low Reliability (Level 3b)

TABLE 3-continued

Bit reliabilities for 64-QAM according to signal constellations shown in FIG. 4.

Constellation	bit i_1	bit q_1	bit i_2	bit q_2	bit i_3	bit q_3
2	Low Reliability (Level 3b)	Low Reliability (Level 3b)	High Reliability (Level 1)	High Reliability (Level 1)	Middle Reliability (Level 2b)	Middle Reliability (Level 2b)
3	Middle Reliability (Level 2b)	Middle Reliability (Level 2b)	Low Reliability (Level 3b)	Low Reliability (Level 3b)	High Reliability (Level 1)	High Reliability (Level 1)
4	High Reliability (Level 1)	High Reliability (Level 1)	Middle Reliability (Level 2a)	Middle Reliability (Level 2a)	Low Reliability (Level 3a)	Low Reliability (Level 3a)
5	Low Reliability (Level 3a)	Low Reliability (Level 3a)	High Reliability (Level 1)	High Reliability (Level 1)	Middle Reliability (Level 2a)	Middle Reliability (Level 2a)
6	Middle Reliability (Level 2a)	Middle Reliability (Level 2a)	Low Reliability (Level 3a)	Low Reliability (Level 3a)	High Reliability (Level 1)	High Reliability (Level 1)

[0098] Moreover Table 4 provides some examples how to combine the constellations for the transmissions 1 to 6 (using 6 different mappings).

TABLE 4

Examples for Constellation Rearrangement strategies for 64-QAM (using 6 mappings) with signal constellations according to FIG. 4 and bit reliabilities according to Table 3.

Trans- mission No.	Scheme 1 (with Constel- lations)	Scheme 2 (with Constel- lations)	Scheme 3 (with Constel- lations)	Scheme 4 (with Constel- lations)
1	1	1	1	1
2	2	3	5	3
3	3	2	6	2
4	4	4	4	6
5	5	5	2	5
6	6	6	3	4

[0099] Two algorithms are given which describe schemes using 3 or 6 mappings overall. The approach using 3 mappings results in less system complexity, however has some performance degradation with respect to the approach using 6 mappings. The mapping for i- and q-bits can be done independently and, hence, in the following the mapping for the i-bits only is described. The algorithms for the q-bits work analog.

64-QAM Algorithms

A. Using 3 Mappings

[0100] 1. Step (1. Transmission)

[0101] 1. Step (1. Transmission)

[0102] Choose Level 1 for i_1

[0103] Choose Level 2 for i_2 (free choice if **2a** or **2b**) ⇒Level 3 for i_3—free choice if **3a** or **3b** ⇒1. Mapping Defined

[0104] 2. Step (2. Transmission)

[0105] Options:

[0106] (a) Choose Level 1 for i_2

[0107] Choose Level 2 for i_3 (free choice if **2a** or **2b**) ⇒Level 3 for i_1—free choice if **3a** or **3b**

[0108] (b) Choose Level 1 for i_3

[0109] Choose Level 2 for i_1 (free choice if **2a** or **2b**) ⇒Level 3 for i_2—free choice if **3a** or **3b** ⇒2. Mapping Defined

[0110] 3. Step (3. Transmission) if (a) in 2. Step

[0111] Choose Level 1 for i_3

[0112] Choose Level 2 for i_1 (free choice if **2a** or **2b**) ⇒Level 3 for i_2—free choice if **3a** or **3b** if (b) in 2. Step

[0113] Choose Level 1 for i_2

[0114] Choose Level 2 for i_3 (free choice if **2a** or **2b**) ⇒Level 3 for i_1—free choice if **3a** or **3b** ⇒3. Mapping Defined

[0115] 4. Step (4., 7., 10, . . . Transmission)

[0116] Choose one out of 3 defined mappings

[0117] 5. Step (5., 8., 11, . . . Transmission)

[0118] Choose one out of 3 defined mappings except the mapping used in previous transmission

[0119] 6. Step (6., 9., 12, . . . Transmission)

[0120] Choose one out of 3 defined mappings except the mapping used in last 2 transmissions

[0121] 7. Step

[0122] Go to 4. Step

B. Using 6 Mappings

[0123] 1. Step (1. Transmission)

[0124] Choose Level 1 for i_1

[0125] Choose Level 2 for i_2 (free choice if **2a** or **2b**) ⇒Level 3 for i_3—free choice if **3a** or **3b** ⇒1. Mapping Defined

[0126] 2. Step (2. Transmission)

[0127] Options:

[0128] (a) Choose Level 1 for i_2

[0129] Choose Level 2 for i_3 (free choice if **2a** or **2b**) ⇒Level 3 for i_1—free choice if **3a** or **3b**

[0130] (b) Choose Level 1 for i_3

[0131] Choose Level 2 for i_1 (free choice if **2a** or **2b**) ⇒Level 3 for i_2—free choice if **3a** or **3b** 2. Mapping Defined

[0132] 3. Step (3. Transmission)

[0133] if (a) in 2. Step

[0134] Choose Level 1 for i_3

[0135] Choose Level 2 for i_1 (free choice if **2a** or **2b**) ⇒Level 3 for i_2—free choice if **3a** or **3b**

[0136] if (b) in 2. Step

[0137] Choose Level 1 for i_2

[0138] Choose Level 2 for i_3 (free choice if **2a** or **2b**) ⇒Level 3 for i_1—free choice if **3a** or **3b** ⇒3. Mapping Defined

[0139] 4. Step (4. Transmission)

[0140] Choose Level 1 for one bit out of i_1, i_2 or i_3

[0141] Choose Level 2 for one out of two remaining bits with following restrictions

[0142] (a1) if in one of the previous transmission **2a** was used for this bit then use **2b**

[0143] (a2) if in one of the previous transmission **2b** was used for this bit then use **2a**

[0144] ⇒Level 3 for remaining bit with following restrictions

[0145] (b1) if in one of the previous transmission **3a** was used for this bit then use **3b**

[0146] (b2) if in one of the previous transmission **3b** was used for this bit then use **3a** ⇒4. Mapping Defined

[0147] 5. Step (5. Transmission)

[0148] Choose Level 1 for one out of two bits not having Level 1 in 4. Step Choose Level 2 for one out of two bits not having Level 2 in 4. Step with following restrictions

[0149] (a1) if in one of the previous transmission **2a** was used for this bit then use **2b**

[0150] (a2) if in one of the previous transmission **2b** was used for this bit then use **2a**

[0151] ⇒Level 3 for remaining bit with following restrictions

[0152] (b1) if in one of the previous transmission **3a** was used for this bit then use **3b**

[0153] (b2) if in one of the previous transmission **3b** was used for this bit then use **3a** ⇒5. Mapping Defined

[0154] 6. Step (6. Transmission)

[0155] Choose Level 1 for bit not having Level 1 in 4. Step and 5. Step

[0156] Choose Level 2 for bit not having Level 2 in 4. Step and 5. Step with following restrictions

[0157] (a1) if in one of the previous transmission **2a** was used for this bit then use **2b**

[0158] (a2) if in one of the previous transmission **2b** was used for this bit then use **2a**

[0159] ⇒Level 3 for remaining bit with following restrictions

[0160] (b1) if in one of the previous transmission **3a** was used for this bit then use **3b**

[0161] (b2) if in one of the previous transmission **3b** was used for this bit then use **3a**

[0162] ⇒6. Mapping Defined

[0163] 7. Step (7., 13., 19., . . . Transmission)

[0164] Choose one out of 6 defined mappings

[0165] 8. Step (8., 14., 20., . . . Transmission)

[0166] Choose one out of 6 defined mappings except

[0167] (a) the mapping used in 7. Step (previous transmission)

[0168] (b) the mapping giving Level I reliability to the same bit as in previous transmission

[0169] 9. Step (9.,15., 21., . . . Transmission)

[0170] Choose one out of 6 defined mappings with giving Level 1 reliability to the bit not having Level 1 in last 2 transmissions

[0171] 10. Step (10., 16., 22., . . . Transmission)

[0172] Choose one out of 3 remaining mappings not used in last 3 transmissions

[0173] 11. Step (11., 17., 23., . . . Transmission)

[0174] Choose one out of 2 remaining mappings not used in last 4 transmissions

[0175] 12. Step (12., 18., 24., . . . Transmission)

[0176] Choose remaining mapping not used in last 5 transmissions

[0177] 13. Step

[0178] Go to 7. Step

[0179] FIG. **5** shows an exemplary embodiment of a communication system to which the present invention can be applied. More specifically, the communication system comprises a transmitter **10** and a receiver **20** which communicate through a channel **30** which can either be wirebound or wireless, i.e. an air inteface. From a data source **11**, data packets are supplied to a FEC encoder **12**, where redundancy bits are added to correct errors. The n bits output from the FEC decoder are subsequently supplied to a mapping unit **13** acting as a modulator to output symbols formed according to the applied modulation scheme stored as a constellation pattern in a table **15**. Upon transmission over the channel **30**, the receiver **20** checks the received data packets, for example, by means of a cyclic redundancy check (CRC) for correctness.

[0180] If the received data packets are erroneous, the same are stored in a temporary buffer **22** for subsequent soft combining with the retransmitted data packets.

[0181] A retransmission is launched by an automatic repeat request issued by an error detector (not shown) with the result that an identical data packet is transmitted from the transmitter **10**. In the combining unit **21**, the previously

received erroneous data packets are soft-combined with the retransmitted data packets. The combining unit **21** also acts as a demodulator and the same signal constellation pattern stored in the table **15** is used to demodulate the symbol which was used during the modulation of that symbol.

[0182] As illustrated in FIG. **6**, the table **15** stores a plurality of signal constellation patterns which are selected for the individual (re)-transmissions according to a predetermined scheme. The scheme, i.e. the sequence of signal constellation patterns used for modulating/demodulating are either pre-stored in the transmitter and the receiver or are signaled by transmitter to the receiver prior to usage.

[0183] As mentioned before, the method underlying the invention rearranges the signal constellation patterns for the individual (re)-transmissions according to a predetermined scheme, such that the mean bit reliabilities are averaged out. Hence, the performance of the FEC decoder **23** is significantly improved, resulting in a low bit error rate (BER) output from the decoder.

What is claimed is:

1. A transmission apparatus for transmitting data comprising:

transmission section that transmits data using one of a plurality of constellation versions in a modulation scheme, each of said constellation versions defining at least one of (i) bit positions in a bit sequence comprising a plurality of bits and (ii) logical values of the bits.

2. A communication system comprising:

a transmitting apparatus according to claim 1; and

a receiving apparatus comprising a reception section that receives data transmitted by said transmitting apparatus.

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